

**Uniformed Services University
of the Health Sciences**

Manuscript/Presentation Approval or Clearance

INITIATOR

1. USU Principal Author/Presenter: Maj Louis J. Marconyak
2. Academic Title: Endodontic Resident
3. School/Department/Center: Keesler Medical Center
4. Phone: 228-376-5181
5. Type of clearance: ___ Paper X Article ___ Book ___ Poster ___ Presentation ___ Other
6. Title: A Comparison of Coronal Tooth Discoloration Elicited by Various Endodontic Reparative Materials
7. Intended publication/meeting: Journal of Endodontics
8. "Required by" date:
9. Date of submission for USU approval: 17 June 2015

CHAIR OR DEPARTMENT HEAD APPROVAL

1. Name: Timothy C. Kirkpatrick, Col, USAF, DC
2. School/Dept.: Keesler Medical Center/Dept of Endodontics
3. Date: 17 June 2015

**Note: It is DoD policy that clearance of information or material shall be granted if classified areas are not jeopardized, and the author accurately portrays official policy, even if the author takes issue with that policy. Material officially representing the view or position of the University, DoD, or the Government is subject to editing or modification by the appropriate approving authority.*

Chair/Department Head Approval: _____



Date 17 June 2015

SERVICE DEAN APPROVAL

1. Name: Col Drew W. Fallis



2. School (if applicable): Air Force Postgraduate Dental School

3. Date: 22 Jun 2015

4. ☐ Higher approval clearance required (for University-, DoD- or US Gov't-level policy, communications systems or weapons issues review").

***Note:** It is DoD policy that clearance of information or material shall be granted if classified areas are not jeopardized, and the author accurately portrays official policy, even if the author takes issue with that policy. Material officially representing the view or position of the University, DoD, or the Government is subject to editing or modification by the appropriate approving authority.

COMMANDER APPROVAL

1. Name:

2. School (if applicable):

3. Date:

4. ☐ Higher approval clearance required (for University-, DoD- or US Gov't-level policy, communications systems or weapons issues review").

***Note:** It is DoD policy that clearance of information or material shall be granted if classified areas are not jeopardized, and the author accurately portrays official policy, even if the author takes issue with that policy. Material officially representing the view or position of the University, DoD, or the Government is subject to editing or modification by the appropriate approving authority.

PDC DEAN APPROVAL

1. Name:
2. School (if applicable):
3. Date:
4. ___ Higher approval clearance required (for University-, DoD- or US Gov't-level policy, communications systems or weapons issues review").

**Note: It is DoD policy that clearance of information or material shall be granted if classified areas are not jeopardized, and the author accurately portrays official policy, even if the author takes issue with that policy. Material officially representing the view or position of the University, DoD, or the Government is subject to editing or modification by the appropriate approving authority.*

Dean/VP Signature/Date

VICE PRESIDENT FOR EXTERNAL AFFAIRS ACTION

1. Name:
2. Date:
3. ___ USU Approved or
___ DoD Approval/Clearance required
4. ___ Submitted to DoD (Health Affairs) on (date):
Or ___ Submitted to DoD (Public Affairs) on (date):
5. ___ DoD approved/cleared (as written) or ___ DoD approved/cleared (with changes)
6. DoD clearance/date:
7. DoD Disapproval/date:

External Affairs Approval

Date

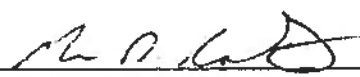
**A Comparison of Coronal Tooth Discoloration Elicited by Various Endodontic
Reparative Materials**

Major Louis Joseph Marconyak, Jr.

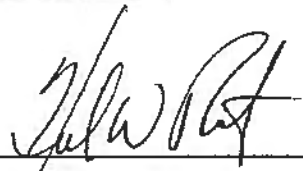
APPROVED:




Colonel Timothy C. Kirkpatrick



Lt Col Mark Roberts



Colonel Howard W. Roberts



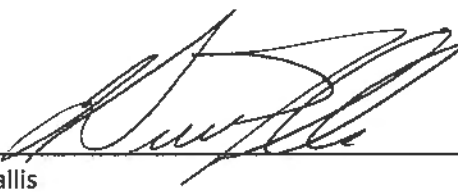
Dr. Arnau Aparicio



Dr. Kent A. Sabey

29 APR 2015
Date

APPROVED:

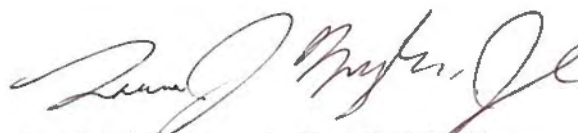


Col Drew W. Fallis
Dean, Air Force Postgraduate Dental School

"The author hereby certifies that the use of any copyrighted material in the thesis/dissertation manuscript entitled:

"A Comparison of Coronal Tooth Discoloration Elicited by Various Endodontic Reporative Materials"

is appropriately acknowledged and, beyond brief excerpts, is with the permission of the copyright owner.

A handwritten signature in dark ink, appearing to read "Louis J. Marconyak, Jr.", written in a cursive style.

Louis J. Marconyak, Maj, USAF, DC
Endodontic Residency Program - Keesler
Uniformed Services University
17 June 2015

A Comparison of Coronal Tooth Discoloration Elicited by Various Endodontic Reparative Materials

Louis J. Marconyak, Jr., DMD, Timothy C. Kirkpatrick, DDS, Mark D. Roberts, DMD, Howard W. Roberts, DDS, Arnau Aparicio, DDS, and Kent A. Sabey, DDS

Objective: To evaluate coronal tooth discoloration of ProRoot® MTA, white ProRoot® MTA, EndoSequence® Root Repair Material, MTA-Angelus®, and Biodentine® when used in an ex-vivo pulpotomy model. **Methods:** Freshly extracted mandibular third molars were collected and stored in 1% Chloramine-T solution. Teeth were randomly assigned into 6 groups (N=15) and stored individually in phosphate-buffered saline at 37°C in 100% humidity. A standardized endodontic access was made in 5 groups. A 3mm-thick increment of reparative material was placed on the pulpal floor, covered by glass ionomer, and restored with composite. Color (CIE L*a*b*) was recorded with the Vita Easy Shade spectrophotometer on the mid-buccal surface at baseline, and after access preparation, material placement, 1, 7, 30, and 60 days. Changes in CIE L*a*b* were measured for each experimental group and compared to ProRoot MTA (positive control) and no treatment (negative control) using the equation $\Delta E = [(L_i - L_0)^2 + (a_i - a_0)^2 + (b_i - b_0)^2]^{1/2}$. **Results:** Mean results were analyzed within each group and between groups using Both Shapiro-Wilk and Bartlett's tests and followed by Friedman's Two-Way Analysis post hoc test ($p < 0.05$). There were no significant differences between white ProRoot MTA, MTA-Angelus, and the positive control groups. EndoSequence Root Repair Material and Biodentine produced significantly less discoloration than white ProRoot MTA, MTA-Angelus, and ProRoot MTA. **Conclusions:** Under the conditions of this study, EndoSequence and Biodentine had significantly less discoloration compared with white ProRoot MTA, MTA-Angelus, and ProRoot MTA. The potential for discoloration may or may not correlate when materials are used clinically.

Key Words

Tooth discoloration, ProRoot MTA, MTA-Angelus, EndoSequence Root Repair Material, Biodentine

Aesthetics play an important role in dentistry today and even a single tooth can have a significant impact on one's quality of life (1). Many materials used in endodontic procedures can lead to tooth discoloration and an unesthetic outcome. Mineral trioxide aggregate (MTA), composed of modified Portland cement with added bismuth oxide (2, 3), was introduced in 1993. In addition to its use as a root-end filling material, it has also been used for pulp capping and pulpotomies, root and coronal perforation repairs, apexification, apexogenesis, regeneration and as a root canal filling material (4). It has been shown to be a biocompatible material with little cytotoxicity (5). Even with its many ideal characteristics for an endodontic reparative material, one area of concern with the use of MTA is tooth discoloration. Gray ProRoot MTA (MTA) has been shown in multiple reports to cause tooth discoloration

(6, 7, 8). This is a significant area of concern for many patients in the esthetic zone. In response to the discoloration traits noted with gray MTA, White ProRoot® MTA (wMTA) containing decreased amounts of iron, aluminum and magnesium was developed. (4,9). ProRoot wMTA (Dentsply Tulsa Dental, Johnson City, TN) and MTA-Angelus (Angelus Solucoes Odontologicas, Londrina, Brazil) are two commercially readily available products containing white MTA. Felman et al, showed minor coronal discoloration with wMTA when used in regeneration procedure (10, 11).

The potential of discoloration associated with the use of MTA has led to a search for an alternative endodontic reparative material, similar in composition that will not cause tooth discoloration. Two of these materials are Biodentine (Septodont, Saint Maur des Fosses, France) and EndoSequence Root Repair Material (ERRM) (Brasseler USA, Savannah, GA). Biodentine is a dentin restorative material composed of tricalcium silicate, calcium carbonate, zirconium oxide powder, and calcium chloride liquid (12). According to the manufacturer, Biodentine has similar indications for use as MTA along with a faster setting time (12). EndoSequence Root Repair Material is composed of calcium silicates, zirconium oxide, tantalum pentoxide, calcium phosphate monobasic, and filler agents. In an animal model, Chen et al, demonstrated that ERRM is a biocompatible material with good sealing ability and had better tissue healing response than MTA (13).

None of these materials, MTA-Angelus, Biodentine or ERRM, has been examined in the aspect of tooth discoloration compared to ProRoot® MTA. Therefore the purpose of this study was to compare the coronal discoloration of gray ProRoot® MTA, white ProRoot® MTA, MTA-Angelus, Biodentine®, and EndoSequence Root Repair Material when used in a pulpotomy procedure.

Materials and Methods

Sample Preparation

Ninety mandibular impacted third molars treatment planned for extraction were collected and stored in 1% Chloramine-T solution. All teeth were evaluated under a dental operating microscope at 12.8x magnification to be completely intact and free of restorations, cracks, and/or defects. Each tooth was stored separately in phosphate-buffered saline solution at 37°C +/- 1°C in 100% humidity throughout the study. The teeth were randomly assigned to six groups (n=15). The teeth in groups 1-5 were endodontically accessed with #4 round and Endo-Z burs in a high speed handpiece with water spray under a dental operating microscope. The buccal enamel-dentin thickness was standardized to 3mm using spring calipers. Teeth were irrigated with 6% NaOCl and dried. All materials were mixed according to manufacture recommendations and placed a 3mm thickness above the orifices and allowed to set. Group 1 – ProRoot MTA, Group 2 – ProRoot wMTA, Group 3 – Biodentine, Group 4 – ERRM, Group 5 – MTA-Angelus, and Group 6 not prepared negative control. A 3mm thickness of glass ionomer (ChemFil Rock shade A-1, Dentsply Caulk, Milford, DE) was placed over each material and allowed to set. The remaining access of each tooth was filled with a composite (Esthet•X HD Dentsply Caulk, Milford, DE). The shade of the composite was matched to the coronal tooth by a prosthodontist and confirmed with a spectrophotometer (VITA Easy Shade; VITA Zahnfabrik, Bad Säckingen, Germany).

Spectrophotometric Analysis

Color was recorded using the Commission Internationale de l'éclairage (CIE) L* a* b* color space. Changes in CIE L*a*b* were measured for each experimental group and compared to ProRoot MTA, Group 1, (positive control) and no treatment, Group 6, (negative control) using the equation

$\Delta E = [(L_i - L_0)^2 + (a_i - a_0)^2 + (b_i - b_0)^2]^{1/2}$. ΔL represents the change in luminosity from black (0) to white (100), Δa represents the change in the red (-80) to green (+80) parameter, and Δb represents the change in the blue (-80) to yellow (+80) parameter. Color values were recorded on all 90 teeth using the VITA Easy Shade spectrophotometer under constant light by the same operator at all time intervals. The device was calibrated before each measurement. Each measurement was repeated 3 times on the mid-buccal surface of each tooth at baseline, access preparation, material placement, 1, 7, 30, and 60 days. The ΔE values that were ≥ 3.3 were acknowledged as having clinically noticeable discoloration (14, 15). Images of each tooth were captured at each interval using a digital camera (Nikon D80, Toyko, Japan).

Statistical Analysis

The data was analyzed using Shapiro-Wilk and Bartlett's tests. Due to abnormalities in both the distribution and variance of the mean data the data was then subjected to Friedman's Two-Way Analysis for ranks at a 95 per cent level of confidence ($p < 0.05$).

Results

The mean values for changes in color caused by the materials are shown in Figure 1. All of the experimental teeth showed clinically noticeable discoloration at day 1, however, from day 7 through day 60, Biodentine and ERRM did not cause clinically noticeable discoloration compared to the negative control, $\Delta E < 3.3$. The teeth with MTA and wMTA exhibited clinically noticeable discoloration ($\Delta E \geq 3.3$) after day 1 of placement which persisted throughout the 60 day experimental period. Although the teeth with MTA-Angelus did not exhibit clinically noticeable discoloration until day 7, the discoloration persisted for the remainder of the 60 day experimental period. While wMTA and MTA-Angelus showed more discoloration compared to MTA at 30 and 60 days, the differences were not significant. Both wMTA and MTA-Angelus both showed significantly higher ΔE value compared to Biodentine and ERRM.

The changes in colors within each group are shown in Figure 2. Photos of a tooth from each sample group at baseline and day 60 are shown in Figure 3.

Discussion

Color changes in teeth can be measured visually and with specific instruments such as a spectrophotometer. The CIE L* a* b* color space system is an arrangement for international standardization on issues of color and is acknowledged by the ISO (16). Spectrophotometric analysis with the Vita Easy Shade was applied because of the technique's sensitivity to small changes in color, repeatability, and objectivity (17).

This study evaluated various endodontic reparative materials in order to determine which would be the best to use in esthetic areas. It was found that ERRM followed by Biodentine exhibited less discoloration over the 60 day period than ProRoot MTA and ProRoot wMTA. Many studies and case reports show that MTA causes discoloration and therefore should be used with caution for the treatment of teeth located in an esthetically important area of the mouth (6-8, 10). MTA has been the material of choice on pulpal tissues; however, ERRM has been shown to have a better tissue healing response than MTA (13).

Bismuth oxide is added to improve the radiopacity of MTA and used in ProRoot wMTA and wMTA Angelus along with other heavy metals. Bismuth oxide is associated with MTA discoloration dissociates into dark color crystals of metallic bismuth and oxygen when exposed to visible and ultraviolet light (10, 18, 19). Over oxidation of bismuth oxide can also lead to discoloration, which can occur when comes into contact with sodium hypochlorite solution, which was used in this study to simulate a clinical pulpotomy (19). In the present study, ERRM and Biodentine, which contain zirconium oxide in place of bismuth oxide as a radiopaquerexhibited less discoloration than the MTAs that contain

bismuth oxide. Thus, concluding that bismuth oxide is one of the main contributors to discoloration (20, 21).

Many studies testing coronal discoloration are done by removing tooth structure below the CEJ, removing the pulp tissue and placing material retrograde (10, 22). In this study, in an attempt to more closely simulate a clinical procedure, an ideal coronal access preparation was made and reparative materials were placed in an orthograde manner. The teeth were then restored with a glass ionomer cement and composite resin restoration. These restorative materials act as a radiopaquer to reduce discoloration, which was still present in some groups. This design allowed a closer clinical comparison of discoloration. Impacted mandibular molars were chosen due to the ability to obtain uniform specimens free from defects and preexisting discolorations. The dentin thickness was standardized at 3mm, however, the dentin thickness may vary considerably in individual teeth and patients which could impact the clinical discoloration noted.

Conclusion

Under the conditions of this study, ERRM and Biodentine had significantly less discoloration compared with white ProRoot MTA, MTA-Angelus, and ProRoot MTA. The potential for discoloration may or may not correlate when materials are used clinically. Additional clinical studies with these materials on anterior teeth are suggested.

Figures

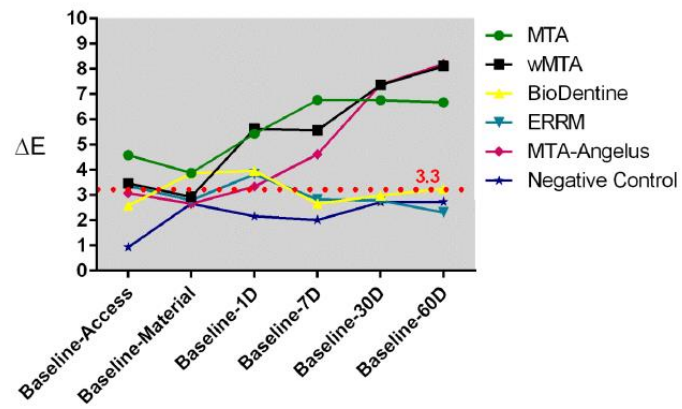


Figure 1. Mean ΔE value changes at each time interval. The dotted line represents clinically noticeable discoloration of $\Delta E \leq 3.3$.

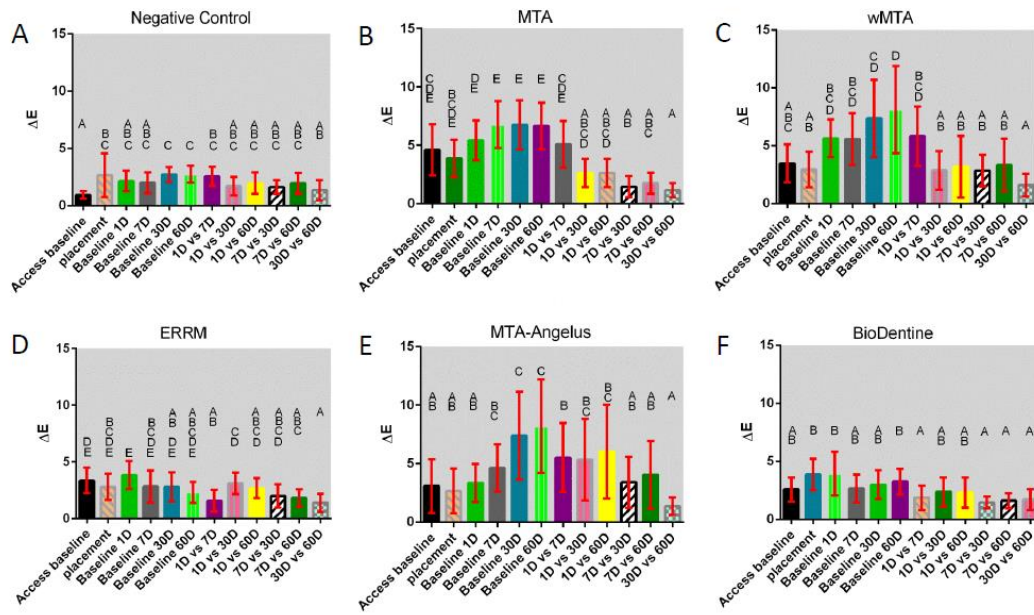


Figure 2. Mean ΔE changes between each time interval within each group: **A.** Negative control, **B.** MTA, **C.** wMTA, **D.** ERRM, **E.** MTA-Angelus, **F.** Biodentine. The vertical lines represent the standard deviation. The capital letters above each interval represent statistically similar groups. Groups are statistically different if they do not have the same capital letter above them.

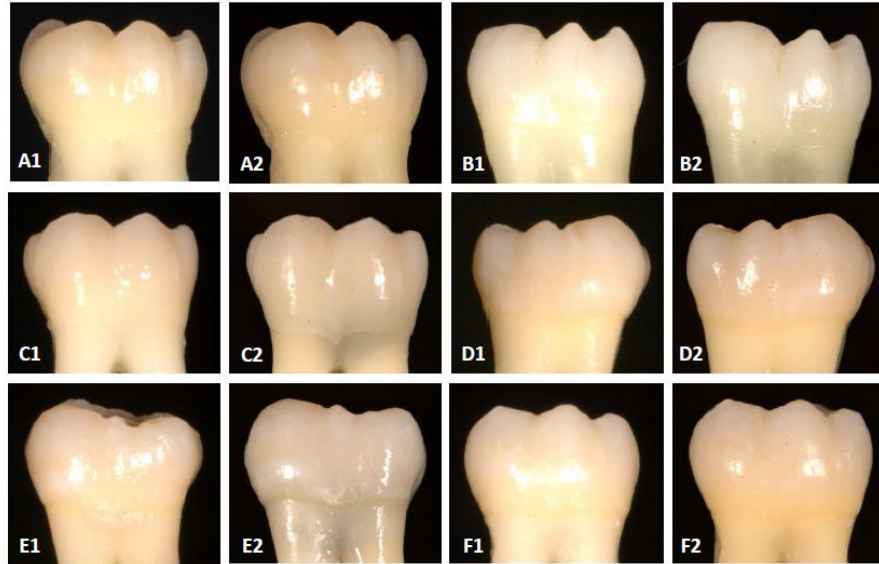


Figure 3. A1. Negative control baseline, A2. Negative control 60D, B1. MTA baseline, B2. MTA 60D, C1. wMTA baseline, C2. wMTA 60D, D1. ERRM baseline, D2. ERRM 60D, E1. MTA-Angelus baseline, E2. MTA-Angelus 60D, F1. Biodentine baseline, F2. Biodentine 60D

References

1. Dugas NN, Lawrence HP, Teplitsky P, Friedman S. Quality of life and satisfaction outcomes of endodontic treatment. *J Endod*. 2002;28:819-27.
2. Parirokh M., Torabinejad M. Mineral trioxide Aggregate: a comprehensive literature review-Part 1: chemical, physical, and antibacterial properties. *J Endod* 2010;36:16-27.
3. Torabinejad M, White DJ. Tooth filling material and use. United States patent number 5,769,638:1995.
4. Parirokh M, Torabinejad M. Mineral Trioxide Aggregate: A Comprehensive Literature Review-Part III: Clinical Applications, Drawbacks, and Mechanism of Action. *J Endod* 2010;36:400-7
5. Torabinejad M, Parirokh M. Mineral trioxide aggregate: a comprehensive literature review. Part 2: leakage and biocompatibility investigations. *J Endod* 2010;36:190-202.
6. Krastl G, Allgayer N, Lenherr P, Filippi A, Taneja Pankaj, Weiger R. Tooth discoloration induced by endodontic materials: a literature review. *Dental Traumatology* 2013;29:2-7.
7. Bortoluzzi EA, Araújo GS, Guerreiro Tanomaru JM, Tanomaru-Filho M. Marginal gingiva discoloration by gray MTA: a case report. *J Endod* 2007;33:325-7.
8. Karabucak B, Li D, Lim J, Iqbal M. Vital pulp therapy with mineral trioxide aggregate. *Dent Traumatol* 2005;21:240-3.
9. Glickman GN, Koch KA. 21st-century endodontics. *J Am Dent Assoc* 2000;131:39-46.
10. Felman D, Parashos P. Coronal Tooth Discoloration and White Mineral Trioxide Aggregate. *J Endod* 2013;39:484-7.
11. Belobrov I, Parashos P. Treatment of tooth discoloration after the use of white mineral trioxide aggregate. *J Endod* 2011;37:1017-20.
12. Laurent P, Camps J, De Melo M, et al. Induction of specific cell responses to a Ca(3)SiO(5)-based posterior restorative material. *Dent Mater* 2008;24:1486-94.
13. Chen I, Karabucak B, Wang C, Wang H, Koyama E, Kohli M, Nah H, Kim S. Healing after root-end microsurgery by using mineral trioxide aggregate and a new calcium silicate-based bioceramic material as root-end filling materials in dogs. *J Endod* 2015;41:389-99.
14. Ruyter IE, Nilner K, Moller B. Color stability of dental composite resin materials for crown and bridge veneers. *Dent Mater* 1987;3:246-51.
15. Khokhar Z, Razzoog M, Yaman P. Color stability of restorative resins. *Quintessence Int* 1991;22:733-7.
16. Ioannidis K, Mistakidis I, Beltes P, Karagiannis V. Spectrophotometric analysis of coronal discolouration induced by grey and white MTA. *Int Endod J* 2013;46:137-44.
17. ALGhazali N, Burnside G, Smith PW, Preston AJ, Jarad FD. Performance assessment of Vita Easy Shade spectrophotometer on colour measurement of aesthetic dental materials. *Eur J Prosthodont Rest Dent* 2011;19:168-74.
18. Valles M, Mercade M, Duran-Sindreu F, et al. Influence of light and oxygen on the color stability of five calcium silicate-based materials. *J Endod* 2013;39:525-8.
19. Camilleri J. Color stability of white mineral trioxide aggregate in contact with hypochlorite solution. *J Endod* 2014;40:436-40.
20. Marciano MA, Costa RM, Camilleri J, et al. Assessment of color stability of white mineral trioxide aggregate angelus and bismuth oxide in contact with tooth structure. *J Endod* 2014;40:1235-40.
21. Kang S, Shin Y, Lee H, Kim S, Shin Y, Jung I, Song J. Color changes of teeth after treatment with various mineral trioxide aggregate-based materials: An ex vivo study. *J Endod* 2015; in press.

22. Ioannidis K, Mistakidis I, Beltes P, Karagiannis V. Spectrophotometric analysis of crown discoloration induced by MTA- and ZnOE-based sealers. *J Appl Oral Sci* 2013;21:138-44.